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ABSTRACT

Adjunct instructional materials are questions and answers keyed to a text. The adjuncts for the study were prepared for textbooks used with two Air Force ROTC courses. Over 400 students at two universities served as subjects. Four experiments were conducted using a counterbalanced repeated measures design. Students used adjunct materials for portions of the text and served as a control for other portions of the text. The results indicate that adjunct materials promote learning of materials directly covered by adjunct questions, but do not contribute to application of the material covered by adjunct questions. The use of adjunct instructional materials is recommended. Further research, especially concerning the effects of various types of questions, also is recommended. (The document concludes with a 16-item bibliography and three appendixes: adjunct materials instructions and questionnaires and the analysis of the data from the study). (Author)

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AFHRL-TR-75-5

AIR FORCE HUMAN RESOURCES LABORATORY

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THE EFFECTS OF ADJUNCT INSTRUCTIONAL MATERIALS EMPLOYED OUTSIDE THE CLASSROOM ON THE PERFORMANCE OF AIR FORCE ROTC STUDENTS

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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July 1975
Final Report for Period August 1972 -- November 1974

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GORDON A. ECKSTRAND, Director
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This study was designed to evaluate the effectiveness of adjunct instructional materials, when used under unstructured conditions outside the classroom. Adjunct instructional materials are questions and answers keyed to a text. The adjuncts for the study were prepared for textbooks used with two Air Force ROTC courses. Over 400 students at two universities served as subjects. Four experiments were conducted using a counterbalanced repeated measures design. Students used adjunct materials for portions of the text and served as a control for other portions of the text. The results indicate that adjunct materials promote learning of materials directly covered by adjunct questions, but do not contribute to application of the material covered by adjunct questions. The use of adjunct instructional materials is recommended. Further research, especially concerning the effects of various types of questions, also is recommended.

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SUMMARY

Purpose

The primary objective of this study was to conduct a systematic evaluation of the effectiveness of adjunct instructional materials, when used in a relatively unstructured environment. Previous studies of adjunct materials have been conducted in relatively structured environments. In most of these studies, subjects were given short passages with adjuncts and were not allowed to refer back to the text.

Method

Four experiments were conducted which were, in effect, two experiments replicated with minor modifications at two institutions. Over 400 Air Force ROTC students served as subjects.

In experiments one and two, junior AFROTC students at two universities were given adjunct materials as part of the reading assignments outside the classroom for a one semester course in aerospace studies. The student text contained 74 articles in 700 pages. Selected articles were assigned for student reading with each chapter. The materials for each chapter were distributed so that approximately one third of the subjects received adjunct materials containing multiple choice questions, one third of the subjects received adjunct materials with constructed response questions, and one third of the subjects received no adjunct materials. The adjunct materials were questions and answers keyed to the text. Students were instructed to read the text before attempting to answer the questions. There were an average of 1.75 adjunct questions per page of text. Assignment of the adjunct materials was rotated in a counterbalanced order so that each subject completed approximately one third of the chapters under each experimental condition (multiple choice questions, constructed response questions, or control). Performance was measured by administering a criterion test after completion of each reading assignment. The tests contained from 43 to 67 questions measuring performance directly covered by adjunct questions (relevant questions) and from 7 to 23 questions measuring performance not directly covered by the adjunct questions (incidental questions). The incidental questions in most cases required the students to apply the facts and principles contained in the text.

In experiments three and four, senior AFROTC students at the two universities completed a ten chapter, 56 page pamphlet as part of a two-week section on military justice. The same instructions for adjunct use were given to these students. The average adjunct question count was 1.75 per page of text. Half of the classes received adjunct materials for the first five chapters. The remaining classes received adjunct materials for the last five chapters. The multiple choice adjunct materials were used in one study and constructed response questions were used in the other. A 50-item criterion test was administered after the students had completed all ten chapters. Separate scores were obtained for the incidental items (20) and relevant items (30) under each experimental condition.

Results

Analysis of the data indicated that:

1. For three of the experiments, scores on the relevant test items of the criterion tests for students who received either type of adjunct questions were significantly higher than the scores of the control group. In one experiment the results were not significant. For this experiment, there were indications from the responses to the questionnaire that some of the subjects may have violated the rule of not using the adjunct materials while serving as a control.
2. In all four experiments, subjects did not perform significantly better on measures of incidental learning when they used adjunct materials than when they did not use adjunct materials.
3. The responses of the subjects to the questionnaire indicated generally favorable attitudes toward the adjunct materials.

The results on the incidental tests may, in part, be explained by differences between the adjunct question and the incidental test items. The adjunct items were designed for retention of facts and principles, but the incidental test questions required application of facts and principles. If the adjunct questions had been application items, results may have been different.

The findings indicated that the following recommendations should be made:

1. Adjunct instructional materials should be utilized in classroom settings for relevant items.
2. Further research is required concerning various questions used as adjuncts and criterion items. The role of application questions is particularly important for further investigation.

PREFACE

The work described in this technical report was accomplished under Project 1710, "Training for Advanced Air Force Systems," Task 171007, "Training Media Design."

Adjunct materials, used in this effort, were developed by McDonnell Douglas Astronautics Co., Eastern Division, St. Louis, Missouri, 63166 under contract F33615-70-C-1705. Systems Research Laboratories, Inc., 2800 Indiana Ripple Rd, Dayton, Ohio, 45444 assisted in the data analysis under contract F33615-74-C-4074.

Appreciation is expressed to staffs of the Air Force ROTC departments at Brigham Young University and Texas A&M University for their assistance in administering adjunct material and collecting data.

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THE EFFECTS OF ADJUNCT INSTRUCTIONAL MATERIALS EMPLOYED OUTSIDE THE CLASSROOM ON THE PERFORMANCE OF AIR FORCE ROTC STUDENTS

I. INTRODUCTION

For many years, researchers in the area of instructional technology have sought to develop techniques which will increase the effectiveness of learning from textual materials. A number of techniques have been developed which have been shown to increase the learning efficiency of the student. The most widely accepted and used of these techniques is programmed learning. Programmed learning has been shown to be an effective technique for promoting learning from text. One of the disadvantages of programmed learning is that the development of programmed instructional materials is expensive. A more economical technique thought to have many of the advantages of programmed learning is the use of adjunct instructional materials. Although this technique is not new, it has received increased attention in recent years.

In this context, adjunct instructional materials are questions, and usually answers, that parallel the text. In normal use of adjunct instructional materials, the student is instructed to read the text, answer the questions, and then check his answer (immediate feedback). Questions may be provided within the text (e.g., at the end of each page or subsection) or at the end of each major section or chapter. The questions also may be printed and packaged separately from the text such as in a workbook. The latter feature makes possible the relatively inexpensive application of the adjunct process to existing textual materials. Although the use of adjunct materials represents a promising technique, additional research is needed to identify the most effective procedures and to identify the types of learning situations for which adjunct materials are likely to be effective.

Background

The technique of using adjunct type questions dates back to early research performed by Pressey (1926, 1927). Pressey developed a simple mechanical device which administered and scored multiple choice questions. It also provided the student with immediate knowledge of results. He proposed the use of the device as the basis for a self-instructional system which would incorporate the basic laws of learning.

The potential economy of using adjunct questions with standard textual materials has led to recent interest in the use of adjunct instructional materials. This interest has produced a series of studies into the nature and use of adjunct materials (Rothkopf, 1966, Rothkopf and Bisbicos, 1967; Frase, 1967; Frase, 1968). These studies have shown under laboratory conditions that the use of adjunct materials does facilitate the learning of textual material.

The Rothkopf and Frase studies have been the subject of sharp criticism from Carver (1972). Carver has criticized these studies for being based on a weak theoretical framework and a methodological approach which provides poor evidence to support generalization to practical classroom usage. Carver has criticized the studies on the following points:

1. Failure to maximize the similarity between the experimental and practical situations. A review of the studies cited above reveals that the subjects were either paid volunteers, or students, participating as a class requirement. The experiments were conducted in a laboratory or similar environment.
2. Failure to permit the student to refer back to previously covered materials or questions. In a practical learning environment, the student normally would be given this freedom.
3. Failure to control for running time. Carver notes that higher performing groups required a longer time to complete the materials. He suggests that the better performance may be a function of the increased time and not the treatment.

Another criticism that can be made of the Rothkopf and Frase studies is that the duration of the experiments has been rather short. Typically the subjects are asked to read a relatively short text (2,000 to 9,000 words) and respond to a post-test the same day. Short experiments of this nature have been criticized by Shulman (1970). The question may be asked: What effect would having the experiment extend over a longer period of time (such as a semester) have on the findings?

Air Force Research

To some extent, research conducted by the Air Force on adjunct instructional materials has offset the criticisms of Carver. Meyer (1965) compared the effectiveness of a training program utilizing adjunct materials with conventional classroom instruction for providing refresher training in aircraft weapons. A group of aircrew members were given a self-study work book containing adjunct questions, the correct answers, and references to the manual containing the answer. Subjects were permitted to refer back to the manual as necessary. Students were instructed to complete the self-study program on their own time (average time 253 minutes). A second group of aircrew members was given conventional classroom instruction (time: 250 minutes) on the subject matter. The group receiving the adjunct materials scored significantly higher on a criterion test administered following completion of training.

Yasutake (1974) used Air Force ROTC students in a study of the effectiveness of adjunct materials for aiding learning of textual materials. Four experimental groups and one control group were used. Students in the experimental groups were provided booklets containing adjunct questions for use with their text books. Booklets for the four experimental groups varied in terms of the type of question (multiple choice or constructed response) and presentation of questions (for use at the end of each page or at the end of each chapter). Referral back to the text was permitted, and time for study was controlled (200 minutes, in the classroom). Yasutake found that students using adjunct materials performed significantly better on relevant criterion test questions (questions directly covered by an adjunct question). However, he found no significant differences in the performance of the control and adjunct groups on incidental criterion test questions (materials not directly covered by the adjuncts). Multiple choice and constructed response adjunct questions were found to be equally effective. Placement of adjunct questions at the end of the chapter was found to be as effective as placement at the end of each page.

Research Needs

The Yasutake study has demonstrated that the use of adjunct instructional materials can improve student performance on relevant test items when students are given the freedom to refer back to the text as necessary. However, proposals for use of the technique in practical situations would be strengthened by further studies in which the artificial control of running time is eliminated. Although this control was necessary to offset the Carver criticism, it is artificial in the sense that students normally control their own reading time while studying. A study is needed to test the effects of adjunct materials in a practical situation which is as near "real world" as possible. A study of this type would allow variables which normally vary from one instructional situation to another to vary naturally. Preferably, such a study should be replicated in several situations using materials for more than one subject matter in a systematic replication (Sidman, 1960). The research described in this report was designed to partially meet this need.

II. PROBLEM

Purpose

The purpose of this study was to conduct a systematic evaluation of the effectiveness of adjunct materials when used in a relatively unstructured environment. The primary goal was to determine the effect on student performance of employing adjunct materials outside the classroom. Previous studies of the effectiveness of adjunct materials have been conducted in highly controlled classroom environments. This study was designed to essentially replicate the Yasutake study (1974) without the strict classroom controls used in that study. The study was conducted in an operational environment to demonstrate the reliability and generality of earlier findings with adjunct instructional materials in a practical situation. Regular classes were employed and students were allowed the option of referral back to the prose instructional materials.

The basic design of the study was systematically replicated in four settings. The replications were made using student populations at two universities (Texas A and M University and Brigham Young University), two divergent kinds of subject matter (aerospace history and military justice), and two course lengths (two weeks and one semester). Findings similar to those of earlier studies should provide evidence of the usefulness of adjunct materials in practical situations.

Objectives

The specific objectives of this investigation were to determine the answers to the following questions under conditions approximating the usual instructional environment:

1. Do students receiving adjunct materials perform better on measures of relevant and incidental learning than students not receiving such instruction?
2. Are adjunct materials using constructed response questions more effective in terms of student performance than multiple choice questions?
3. Do the students using adjunct instructional materials follow the general procedures suggested?
4. What is the general attitude of students toward the use of adjunct instructional materials outside the classroom?

III. METHOD

Subjects

The subjects for the study were junior and senior college students enrolled in the Air Force Reserve Officer Training Corps (AFROTC) programs at Texas A and M University (Texas A&M) and Brigham Young University (BYU) during the fall of 1972. At Texas A&M, 143 juniors and 124 seniors participated in the study. At BYU, 66 juniors and 109 seniors participated. The total subject population was 442.

Materials

Aerospace Studies 300 Instructional Materials. A two-volume text, *Readings in Growth and Development of Aerospace Power,* served as a basic source book for students in Aerospace 300 at both universities. The 700 page text contains 74 articles which range in length from 2 to 20 pages. Students were assigned selected articles from the text as homework and tested periodically on the assigned materials.

An analysis of the content of the text was made to identify important items of information. Then, adjunct instructional materials (questions with text references and a separate sheet with the answers) were developed with the intent of requiring students to demonstrate their understanding of the important items of information. Each adjunct question was prepared in two formats, multiple choice (MC) and constructed response (CR). An average of 1.75 adjunct questions were prepared for each page of instructional materials. Two sets of adjunct questions (either MC or CR), the answers, and page references were then assembled into packets with the questions on the first page(s) and the answers and references on the following page(s). The adjunct materials were prepared under contract by McDonnell Douglas Aircraft Corporation.

Aerospace Studies 300 Evaluation Materials. The contractor who prepared the adjunct questions also developed the evaluation instrument. It consisted of a pool of 287 test items covering material in the 74 articles of the text. Of these, 202 concerned information specifically covered by one of the adjunct questions. These items were classified as relevant test items. Approximately half of these questions were identical to the adjunct questions. The other half were roughly equivalent to the adjunct questions but with minor modifications. The remaining 85 questions concerned materials contained in the reading but not specifically covered by adjunct materials. These items usually required an application of the facts or principles in the text to a hypothetical situation. They were classified as incidental test items. All test items were presented in the multiple choice format.

Aerospace Studies 400 Instructional Materials. The book, the *Military Justice System,* was used as a text for Aerospace Studies 400 at both universities. The book contains 56 pages of textual materials supported by 100 pages of appendices concerning the uniform code of military justice. The procedures used to develop adjunct materials for Aerospace Studies 300 also were used to prepare adjunct questions for the military justice text. A total of 98 adjunct questions were prepared (1.75 per page) in the MC and CR formats. The adjunct materials were assembled into two packets of questions, answers, and references. Each packet contained adjunct materials for approximately half of the text (five chapters). The adjunct materials were developed by the same contractor who developed the materials for the AS 300 course.

Aerospace Studies 400 Evaluation Materials. Twenty-four incidental test items were developed to measure knowledge of materials not directly covered by adjunct questions. As in Aerospace 300, the incidental test items differed from the relevant test items, in that most incidental test items required an

application of facts or principles, while the relevant test items required the direct recognition of a specific fact or principle. A 50 item evaluation instrument was then prepared by selecting 30 items from the questions used as adjunct materials and 20 items from the pool of incidental test items. Half of the relevant items and half of the incidental items were from the first half of the text. The remaining items covered the second half of the text. All test items were presented in the multiple choice format.

Adjunct Materials Instructions. A set of instructions was developed and issued to all students before the adjunct materials were assigned. The instructions recommended that the student read the assignment, answer the adjunct questions, correct the answers, and then review missed questions. The detailed instructions are in Appendix A.

Adjunct Materials Questionnaire. A questionnaire was developed to assess the extent to which the students followed the instructions to read the text before answering questions and to avoid using adjuncts when serving as a control group. The questionnaire also included questions designed to measure student attitude toward the adjunct materials. The Adjunct Materials Questionnaire is in Appendix B.

Experimental Design

A basic experimental design was developed and replicated systematically by varying the location, subject matter, and course length. The basic experimental design provided for comparison of the performance of students on criterion tests when they used adjunct materials with the performance of the same students when they did not use adjunct materials. This was accomplished by assigning units of reading materials for which adjunct materials were provided and units of reading materials for which adjunct materials were not provided. The materials were assigned as homework. Assignments were made in a counterbalanced order so that each student used adjunct materials part of the time and served as a control subject at other times. After reading assignments had been completed, the students were given criterion tests to measure their retention. The criterion tests contained both relevant and incidental test items. The relevant and incidental test items were scored separately to provide measures of relevant and incidental learning.

In effect, four experiments were conducted. Two experiments were conducted at each institution, one using juniors and one using seniors. For convenience in describing the experiments and results, each experiment was assigned an identification number as indicated in Table 1.

Table 1. **Criterion Tests**

Experiment	Class	Institution	Subject
1	junior	Texas A & M	Aerospace History
2	junior	BYU	Aerospace History
3	senior	Texas A & M	Military Justice
4	senior	BYU	Military Justice

Procedures

Experiment 1 and 2. The juniors at both institutions employed adjuncts for one semester. The experimenter conducted a conference with ROTC faculty members at both universities and secured agreement to utilize the adjunct instructional materials with all members of the junior class. The class at Texas A&M was divided into ten sections with four instructors. The class at BYU was divided into four sections with two instructors. Students at Texas A&M were assigned 24 of the 74 articles. Students at BYU were assigned 40 articles.

An assignment matrix was developed for each ROTC department. Reading materials were divided into units. Sections were assigned to treatments by units in a counterbalanced order. Assignments to treatments were rotated so that one third of the units were completed under treatment one, MC (multiple choice); one third under treatment two, CR (constructed response); and one third under treatment three, C (control, reading materials without adjunct questions). A quiz was administered following each unit. Texas A&M was scheduled to administer six quizzes and BYU was scheduled to administer nine quizzes. However, administrative problems were encountered at Texas A&M which prevented strict adherence to the planned procedures. On one occasion, students inadvertently were not given the adjunct instructional materials

according to the plan. This group was used as an additional control group for data analysis. The staff at Texas A&M also decided to eliminate one of the quizzes. This required an additional adjustment in the data analysis procedures.

Students were assigned chapters in the text at the beginning of each unit of instruction. At the time the assignments were made, the students who were to use adjunct materials were given packets containing either the MC or CR adjunct materials and instructions for their use (Appendix A). Students in the control groups were encouraged to avoid using the adjunct materials given to students in the other sections.

At the conclusion of each reading assignment, a ten item quiz was administered. The ten items for each quiz were selected by the using university from the pool of items. An attempt was made to include some incidental questions on each quiz. Five quizzes of 10 items each were given at Texas A&M with a total of 43 relevant items and 7 incidental items. Nine quizzes of 10 items each were given at BYU with a total of 67 relevant items and 23 incidental items. For Texas A&M, each quiz score served as a separate measure of the effectiveness of the treatment. It was necessary to treat each score as a separate measure since an unequal number of quizzes was administered under each treatment (due to the elimination of the one quiz). For BYU, the quiz scores for each treatment were totaled to provide the measure of the effectiveness of each treatment.

After each quiz, the students were rotated to a new treatment and given the appropriate materials. After the final quiz, the students were given the anonymous questionnaire (Appendix B).

Experiment 3 and 4. Seniors at Texas A&M and BYU were given adjunct materials for use with the military justice block of instruction (approximately two weeks). The class at Texas A&M was divided into six sections with two instructors. The class at BYU was divided into four sections with two instructors. The sections were divided and assigned to treatments so that half of the sections received adjunct materials for the first half of the text and half of the sections received adjunct materials for the second half of the text. Each section served as a control group for the portion of the course for which adjunct materials were not provided. Multiple choice adjunct materials were provided at BYU and constructed response adjuncts were provided at Texas A&M. Instructions for the use of adjunct materials (Appendix A) were given at the time the materials were distributed. Students who did not receive adjuncts were encouraged not to use the adjunct materials provided to the other sections.

At the end of the military justice block of instruction, a 50 item test was given at both universities. Thirty items in each test were relevant and 20 items were incidental. Instructors at each institution selected the test items for local use to conform with the 30/20 mix of relevant/incidental items. The test items were divided equally between the first half and second half of the military justice reading assignment. There were 15 relevant items and 10 incidental items covering the first half of the reading assignment, and a like number of items covering the second half. The anonymous questionnaire was administered immediately following administration of the criterion test.

Data Analysis

Transformation of Scores. Since different tests were used to measure achievement under the different experimental conditions, it was necessary to transform the test scores into a standard measure before comparisons could be made. This was accomplished by transforming the test scores into standard scores. The standard scores were further transformed into T scores with a mean of 50 and a standard deviation of 10 to simplify computation and to avoid the use of negative numbers.

Regression Analysis. In an experiment of this type, variables other than the experimental variable can influence the criterion measures. This may result in experimental error which can lead to erroneous interpretations of the results of the experiment. There are statistical techniques which may be used to control the effects of these types of variables. Therefore, it is important that statistical controls are used for as many of these variables as possible. In the present study, two types of variables were identified as having possible effects on performance. These were subject variables (aptitude, motivation, study habits, etc.) and situational variables (instructor, time of day, etc.). Multiple regression techniques provide effective methods for statistically controlling the effects of these types of variables. Multiple regression was used to analyze the data collected in this study.

Using multiple regression techniques, the problem of determining the effect of a variable (such as a treatment) is approached by determining what portion of the variance of the criterion scores is accounted for by the variable. This is accomplished by developing two multiple regression equations (or models) to

predict the criterion scores. The first model (called the full model) includes information on the variable of interest and any control variables. The second model (called the restricted model) is the same as the full model except that information on the variable of interest is omitted. The squared multiple correlation coefficient (RSQ) obtained by using each model to predict the criterion represents the percent of the variance accounted for by the variables included in the model. Thus, the percent of variance accounted for by the variable of interest can be obtained by subtracting the RSQ for the restricted model from the RSQ for the full model (i.e., $RSQ_f - RSQ_r$ = percent of variance accounted for). A statistical test can then be used to determine if the percent of variance accounted for is statistically significant. When the percent variance accounted for is statistically significant and the variable is categorical (such as treatment or group membership) the conclusion may be made that the treatment means are significantly different.[1]

Separate regression analyses were made for each experiment. Details of the analyses and the specific regression models are presented in Appendix C. The general questions of the study were restated in more specific terms to provide a basis for developing the analyses. The analyses were designed to answer the following questions:

Question 1: Is there an interaction between treatments and sections for relevant items of the criterion test (i.e., is the effect of each treatment the same for all sections)?

Question 2: Is there an interaction between treatments and sections for incidental items of the criterion test (i.e., is the effect of each treatment the same for all sections)?

Question 3: Are the mean scores of the subjects on the relevant items of the criterion tests significantly different when the subjects have used multiple choice or constructed response adjunct materials than when they have not used adjunct materials?

Question 4: Are the mean scores of subjects on incidental items of the criterion tests significantly different when the subjects have used multiple choice or constructed response adjunct materials than when they have not used adjunct materials?

Question 5: Are the mean scores of subjects on the relevant items of criterion tests significantly different when the subjects have used multiple choice adjunct materials than when they have used constructed response adjunct materials?

Question 6: Are the mean scores of subjects on the incidental items of the criterion tests significantly different when the subjects have used multiple choice adjunct materials than when they have used constructed response adjunct materials?

Additional Analyses. A further analysis was made to provide additional information for use in evaluating the effects of the adjunct materials. In this analysis, the proportions of the variance of the criterion scores accounted for by two additional variables, section and instruction, were computed. Information on these variables was indirectly included in the regression analysis as part of the control variable (subject). However, it was not possible to determine the influence of the section and instructor variables from this analysis. Thus, the additional computations were required. The proportions of the variance were computed from additional regression models. The models and procedures used are described in Appendix C.

The Adjunct Materials Questionnaire (Appendix B) was analyzed by recording the proportions of responses relating first to conformity with directions and second to attitudes toward adjunct materials. The analyses were designed to answer the questions posed by objectives 3 and 4, Section 2.

IV. RESULTS

Effects of Adjunct Materials

The effects of the adjunct materials on performance were evaluated by comparing the mean scores for subjects when they used adjunct materials with their mean scores when they did not use adjunct materials. The results obtained from the relevant and incidental criterion test items are discussed separately below.

Mean scores were computed for each treatment condition for each section. Examination of the means revealed that for Experiment 1 (Texas A&M, Aerospace Studies) the means for one section (Section Three)

[1] For a more thorough discussion of this approach see Ward and Jennings (1973) or Kelley *et al.* (1969).

deviated markedly from the other section means. Such a large deviation may indicate that uncontrolled factors influenced performance in that section which did not influence the performance in the other sections. Since the presence of uncontrolled factors in a single section would contaminate interpretation of the results, a decision was made to eliminate the data from section three from the analysis.

Relevant Test Items. The mean scores of the subjects on the relevant test items of the criterion tests are presented in Table 2. Examination of the table reveals that the mean scores for the subjects were consistently higher when adjunct materials were used. Comparison of the results for the multiple choice and constructed response adjunct materials used in Experiments 1 and 2 indicated that the subjects' scores were higher for both types of adjunct materials.

Table 2. **Mean Scores by Treatment for Relevant Test Items**

Treatment	Experiment			
	1	2	3	4
MC	52.94	52.49		53.53
CR	49.57	51.80	50.87	
C	47.30	45.72	49.12	47.47

The regression analysis procedures described in Section 3 were used to test the significance of the differences between the observed means. The results of this analysis are presented in Tables 3 and 4. Tests were made to determine if an interaction exists between section and treatment (Question 1, Section 3). The results of these tests are presented in Table 3. As may be seen from the table, the F values obtained were not significant at the .05 level of confidence.

Table 3. **Results of the Tests of the Significance of the Interaction Between Treatments and Sections for Relevant Test Items**

Experiment	RSQ_f	RSQ_r	Pct. Var. Acct. for	F	df	p
1	.3764	.3490	2.74	.85	24/465	.6701
2	.6049	.5616	4.33	1.47	9/121	.1648
3	.7461	.7139	3.22	.65	20/103	.8622
4	.7204	.7180	0.24	.08	1/ 98	.9997

Table 3 presents the results of the tests of the significance of the differences observed between the treatment means in the four experimental situations (Question 3, Section 3). Significant differences (at the .05 level) were observed for Experiments 1, 2, and 4. For Experiment 3, the differences between means is not significant at the .05 level of confidence. However, the level of probability associated with the F value obtained (P = .0568) is only slightly above the .05 level.

Table 4. **Results of the Tests of Significance of the Differences Between Treatment Means for Relevant Test Items**

Experiment	RSQ_f	RSQ_r	Pct. Var. Acct. for	F	df	p
1	.3490	.3003	4.87	18.28	2/489	<.0000
2	.5616	.4688	9.28	13.76	2/130	<.0000
3	.7139	.7055	.84	3.61	1/123	.0568
4	.7180	.5934	12.46	47.72	1/108	<.0000

Since only two treatments were used in Experiment 4, it is clear that the mean for the adjunct condition is significantly higher than the mean for the control condition. It is also clear for Experiments 1 and 2 that the mean for the multiple choice adjunct materials is significantly higher than the mean for the control condition. However, it is not possible to tell from this analysis whether the means for the constructed response materials are significantly higher than the means for the control condition, or whether the means for the multiple choice adjunct materials are significantly higher than the means for the constructed response adjunct materials. An additional analysis was required to test the significance of the difference between these means.

The significance of the differences between the paired means was tested using the Schaffé technique for multiple comparisons. The results of this analysis are presented in Table 5. For Experiment 1, an F value of 12.00 was obtained for the comparison of the means for the multiple choice and constructed response adjunct materials. This F value is significant at the .01 level of confidence. An F value of 7.09 was obtained for the comparison of constructed response adjunct materials and control condition (Question 5, Section 3). This F value is significant at the .05 level of confidence.

Table 5. **Results of Scheffé Test for Multiple Comparisons for Relevant Test Items, Experiments 1 and 2**

Experiment	Required F' .05	Required F' .01	Observed F
1 A&M Aerospace	(df = 2/488)	(df = 2/488)	
MC and CR	6.04	9.32	12.00
CR and Control	6.04	9.32	7.09
2 BYU Aerospace	(df = 2/128)	(df = 2/128)	
MC and CR	6.14	9.56	.24
CR and Control	6.14	9.56	18.16

For Experiment 2, an F value of .24 was obtained for the comparison of the mean scores for the multiple choice and constructed response adjunct materials. This F value does not meet the requirement for significance at the .05 level. An F value of 18.16 was obtained for the comparison of the means obtained for the constructed response adjunct materials and the control condition. This F value is significant at the .01 level of confidence.

Incidental Test Items. The mean scores of the subjects on the incidental items of the criterion tests are given in Table 6. Examination of the table reveals that the means for the control condition are higher for three of the four experiments. In the first experiment, the mean for the constructed response adjunct condition was higher.

Table 6. **Mean Scores by Treatment for Incidental Test Items**

Treatment	Experiment 1	2	3	4
MC	49.48	49.40		49.72
CR	51.18	50.25	48.93	
C	49.48	50.33	51.06	50.27

The regression analysis techniques described in Section 3 were used to test the significance of differences of the means for the incidental item test results. The results of the tests for interaction between treatment and section (Question 2, Section 3) are given in Table 7. As may be observed from the table, the tests for Experiments 1, 2, and 4 were not significant, indicating that the effects of the treatments were consistent across sections. The test for interaction for Experiment 3 is significant ($p = .0182$). Examination of the section means for each treatment revealed no consistent pattern.

Table 7. **Results of the Tests of the Significance of the Interaction Between Treatments and Sections for Incidental Test Items**

Experiment	RSQ_f	RSQ_r	Pct. Var. Acct. for	F	df	p
1	.4002	.3450	5.52	.90	22/215	.5962
2	.3888	.3725	1.63	.36	9/121	.9520
3	.7021	.5911	11.10	1.92	20/103	.0182
4	.6528	.6367	1.61	.45	1/ 98	.9150

The results of the tests of the differences (Question 4, Section 3) between the means for Experiments 1, 2, and 4 are given in Table 8. The test for significance of differences between means was not made for Experiment 3 due to the presence of the interaction. Examination of the table reveals that the means obtained in Experiments 1, 2, and 4 are not significantly different (at the .05 level of confidence.)

Table 8. **Results of the Tests of Significance of the Differences Between Treatment Means for Incidental Test Items**

Experiment	RSQ_f	RSQ_r	Pct. Var. Acct. for	F	df	p
1	.3450	.3380	.71	1.28	2/237	.2802
2	.3725	.3707	.18	.19	2/130	.8316
3*						
4	.6367	.6359	.08	.24	1/108	.6325

*Significance of the differences between means was not tested because of the observed interaction.

Contributions of Treatment and Other Factors to Performance. To provide an additional basis for evaluating the relative effect of the treatments on performance, the proportion of variance accounted for by three other variables—subject, instructor, and section were computed. This information is summarized in Table 9 for relevant test items and in Table 10 for incidental test items. Both tables indicate that the subject variables account for the largest proportion of the variance. For the relevant test items, the treatment variable, with the exception of Experiment 3, accounted for the next largest portion of the variance.

Table 9. **Proportion of Variance Accounted for by Variables Influencing Performance for Relevant Test Items**

Source	Proportion of Variance Accounted for			
	1	2	3	4
Treatment	.0487	.0927	.0077	.1247
Treatment–Section Interaction	.0274	.0433	.0329	.0023
Subjects*	.3003	.4688	.7055	.5934
Sections	(.0324)	(.0750)	(.0698)	(.0662)
Instructor	(.0106)	(.0409)	(.0276)	(.0521)
Unexplained Subject Variance	(.2679)	(.3938)	(.6357)	(.5272)
Unexplained Error Variance	.6236	.3951	.2539	.2796

*Total variance due to subjects is composed of variance due to sections and unexplained subject variance. Variance due to instructor is included in variance due to sections.

Table 10. **Proportion of Variance Accounted for by Variables Influencing Performance on Incidental Test Items**

Source	Proportion of Variance Accounted for			
	1	2	3	4
Treatment	.0044	.0018	.0114	.0008
Treatment–Section Interaction	.0500	.0162	.1109	.0162
Subjects*	.3522	.3707	.5747	.6359
Sections	(.0376)	(.0062)	(.0733)	(.0774)
Instructor	(.0245)	(.0048)	(.0381)	(.0433)
Unexplained Subject Variance	(.3146)	(.3645)	(.5014)	(.5585)
Unexplained Error Variance	.5933	.6112	.2979	.3472

*Total variance due to subjects is composed of variance due to sections and unexplained subject variance. Variance due to instructor is included in variance due to sections.

Questionnaire Results

Conformity to Suggested Directions. The results of the questionnaire items (Appendix B) dealing with conformity to suggested directions are shown in Table 11. Students were free to utilize the adjunct instructional materials in a manner of their own choosing. Responses to the first statement indicate that student use of adjunct varied considerably among the experimental groups. Generally, the seniors (Experiments 3 and 4) tended to make greater use of the adjunct materials than the juniors. The juniors (Experiments 1 and 2) tended to utilize the adjunct materials for test study purposes (responses to the second questionnaire statement) more than the seniors.

Conformity to the suggestion of reading the assignment before the adjunct questions varied between the experiments by a proportion of .53 and .66 (responses to the third statement). This suggested that slightly better than half of the students followed the suggested procedure.

Subjects were encouraged to avoid the use of adjunct instructional materials when serving in the control group. There was a greater conformity to this direction at BYU than at Texas A&M (responses to the fourth questionnaire statement). Of particular interest is the relatively high degree of nonconformity by the seniors at Texas A&M (Experiment 3), and the high proportion of other responses by the seniors at BYU (Experiment 4).

Attitude Toward Adjunct Instructional Materials. The results of student responses to the section of the Adjunct Materials Questionnaire (Appendix B) dealing with attitude toward the adjuncts are shown in Table 12. The first five statements are arranged in a descending order of positive affect toward adjunct materials (for the actual order of presentation, see Appendix B). It may be seen that students were generally favorable toward adjunct materials with a proportion of between .74 and .87 having a desire for such items in other classes (first response statement). The remaining responses shift proportionally from yes to no as attitude reflected by the statements changes from positive to negative with the lowest proportion of yes responses to the most negative statement (fifth). The sixth response statement dealt only with the students receiving two types (MC/CR) of adjunct questions. The majority of students preferred the multiple choice (MC) adjunct questions to the constructed response (CR).

V. CONCLUSIONS, DISCUSSION, AND RECOMMENDATIONS

Conclusions

Analysis of the data collected in the four experiments suggests that the use of adjunct instructional materials in the typical ROTC classroom environment has the following effects:

1. Students perform better on measures of relevant learning when they have used adjunct instructional materials than when they have not used adjunct materials.
2. Students do not perform better on measures of incidental learning when they have used adjunct instructional materials than when they have not used adjunct materials.

Table 11. **Proportion of Subject Responses Conforming with the Suggested Directions**

Questionnaire Statement	Experiment 1			Experiment 2			Experiment 3			Experiment 4		
	Yes	No	Other*	Yes	No	Other*	Yes	No	Other*	Yes	No	Other*
I used adjuncts with most of the reading assignments.	.29	.71	.00	.45	.54	.01	.60	.39	.01	.49	.46	.05
I used adjuncts only to study for tests.	.81	.19	.00	.62	.38	.00	.46	.53	.01	.40	.55	.05
I read the reading assignment before looking at adjunct questions.	.56	.43	.01	.59	.41	.00	.66	.33	.01	.53	.41	.06
When my section didn't have the adjuncts I looked at the adjuncts from another section.	.16	.84	.00	.00	1.00	.00	.36	.63	.01	.02	.88	.10

*Neither response, both responses, or a written response.

Table 12. **Proportion of Subject Responses Indicating General Attitude Toward Adjunct Questions**

Questionnaire Statement	Experiment 1			Experiment 2			Experiment 3			Experiment 4		
	Yes	No	Other*	Yes	No	Other*	Yes	No	Other*	Yes	No	Other*
I would like to have adjunct questions for other classes.	.82	.16	.02	.74	.22	.04	.87	.12	.01	.84	.08	.07
I thought the adjuncts helped me to study the reading assignment.	.61	.39	.00	.70	.28	.02	.84	.13	.03	.70	.19	.11
The adjunct questions did not help or hinder me in studying.	.34	.66	.00	.30	.64	.06	.21	.74	.05	.11	.78	.11
I would have learned the material better studying my own way without the adjunct materials.	.18	.82	.00	.12	.84	.04	.08	.90	.02	.09	.84	.07
The adjunct questions were a waste of my time.	.12	.88	.00	.07	.89	.04	.02	.97	.01	.02	.91	.07
I preferred the multiple choice adjunct questions to the constructed response.	.89	.11	.00	.76	.22	.02		†			†	

*Neither response, both responses, or a written response.
†Experiment 3 and 4 used only one type of adjunct.

3. Neither the multiple choice nor constructed response form of adjunct question is consistently superior to the other for promoting learning.

4. Student populations vary in the degree to which they follow recommended procedures for using adjuncts.

5. Students have a generally favorable attitude toward the use of adjunct materials.

Discussion

Previous studies conducted under controlled conditions have shown that the use of adjunct instructional materials can improve learning of relevant materials. The present study has verified the findings of the earlier studies under less controlled conditions. The results were verified in the more nearly "real world" environment of the university classroom and over a longer period of time (up to one semester). Replication of the results under the more practical conditions used in this study support generalization of the results to the classroom and help to justify use of the technique in the classroom. The fact that the basic experiment was replicated with four subject populations and two subject areas further support this generalization.

The results of studies of the effectiveness of adjunct materials for promoting learning of incidental materials have been inconclusive. Some studies have reported increased learning of incidental materials when adjuncts are used. Other studies have found no significant differences. In the present study, adjunct materials did not significantly affect learning of incidental materials in any of the four experiments. A number of explanations may be offered to account for the failure of the adjunct questions to improve incidental learning.

One explanation would be that the adjunct questions used in the study were not suitable for eliciting incidental learning. It may be that the use of a more comprehensive type of adjunct question is necessary to elicit incidental learning. To effectively produce incidental learning, it may be necessary for adjunct questions to be constructed so that they require the student to think about the materials in general rather than simply recall specific facts or principles. Questions requiring students to think or apply their knowledge are often called application questions. The incidental test items used in this study were application questions which required application of previously learned principles. However, the questions used as adjuncts were not application questions and did not force the students to apply the knowledge acquired while they were still studying the materials. It could be argued that if application questions had been used as adjuncts, forcing the students to apply the knowledge while still fresh, incidental learning may have occurred. A study by Watts and Anderson (1971) provides support for this hypothesis. The results of that study indicated that application questions used as adjuncts are more effective than retention questions for promoting learning as measured by both retention and application criterion test questions.

Another plausable explanation for the failure of the adjunct questions to elicit incidental learning is that they may not have been based on meaningful passages of the text or that the questions were not "meaningful." Rickards (1973) conducted an experiment in which "meaningful" questions (requiring organization of facts in relation to more inclusive concepts) were used as adjuncts. The meaningful questions were found to be significantly more effective than adjunct questions which require rote learning of facts or ideas.

Recommendations

Although a significant amount of research has been conducted on the use of adjunct instructional materials, many questions remain to be answered. The following recommendations are made:

1. Adjunct instructional materials should be employed in classroom settings to enhance relevant learning.

2. A thorough review of the literature on learning from prose should be made. The review should include: (a) research of the effects of meaningfulness on learning and (b) research on the nature and effects of various types of questions employed as adjunct materials.

3. Research should be conducted to clarify the effects of various types of questions. The research should include questions related to simple facts, questions designed to require the student to organize facts in relation to a more general concept (meaningfulness), questions designed to

require the student to apply factual knowledge, and questions designed to require the student to apply principles discussed in the text.

4. Research studies should be systematically replicated using different subject populations and different types of subject matter. The research should be conducted in environments which will permit generalization to practical, everyday learning situations.

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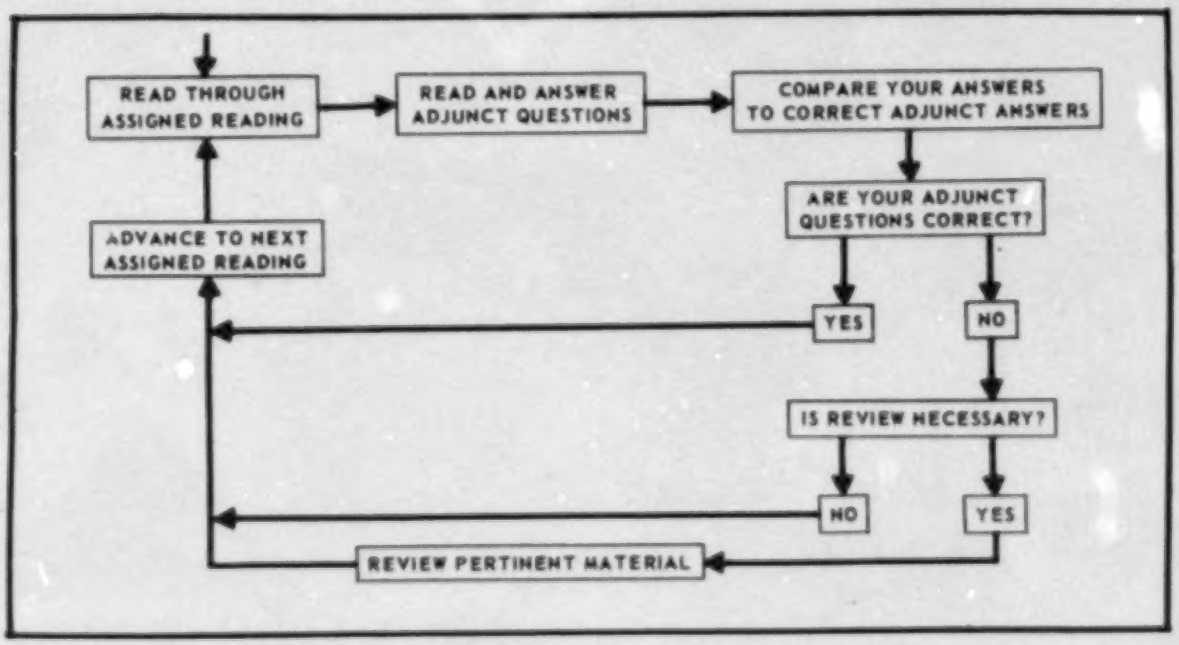
APPENDIX A: ADJUNCT MATERIALS INSTRUCTIONS

INSTRUCTIONS FOR USE

The adjunct questions you have received will help you learn your course material. Research has shown that you will gain the most if you follow the rules given below:

1. Read your text assignment without looking at the adjunct questions.
2. Immediately after reading the text, answer all the adjunct questions.
3. Compare your answers with the answers in the adjunct materials.
4. Review the text (at the page and paragraph indicated) for information concerning the questions you missed.
5. Read the next reading assignment and then repeat the cycle.

The chart below illustrates this process.



Following each adjunct question is a text reference in parenthesis. The first number in the parenthesis is the page and the second number is the paragraph. The paragraphs are numbered from the page where they begin.

APPENDIX B: ADJUNCT MATERIALS QUESTIONNAIRE

DO NOT WRITE YOUR NAME ON THIS QUESTIONNAIRE. PLEASE READ ALL THE STATEMENTS BEFORE MAKING ANY ANSWERS, THEN ANSWER EACH STATEMENT BY PLACING AN "X" UNDER EITHER YES OR NO. IF YOUR ANSWER IS NEITHER YES NOR NO, SELECT THE ANSWER WHICH IS THE CLOSEST TO YOURS.

STATEMENTS	YES	NO
I used the adjuncts with most of the reading assignments.	____	____
I used the adjuncts only to study for tests.	____	____
I read the reading assignment before looking at the adjunct questions.	____	____
I preferred the multiple choice adjunct questions to the constructed response.	____	____
When my section didn't have the adjuncts I looked at the adjuncts from another section.	____	____
I thought the adjuncts helped me to study the reading assignment.	____	____
I would like to have adjunct questions for other classes.	____	____
I would have learned the material better studying my own way without the adjunct materials.	____	____
The adjunct questions did not help or hinder me in studying.	____	____
The adjunct questions were a waste of my time.	____	____

APPENDIX C: DATA ANALYSIS

C-1 INTRODUCTION

A multiple regression analysis was used to analyze the results of the study. Details of the analysis used are described in the following sections.

C-2 PREDICTION VECTORS

The data from the four experiments were coded into four matricies for use in the analysis. To facilitate coding, unique numbers were assigned to each treatment-section combination. The numbering system is shown in Figures C1 and C2. The matricies contained the following vectors:

Y = the criterion score

X_1 = 1 if the criterion score is from treatment-section combination 1, 0 if otherwise

X_2 = 1 if the criterion score is from treatment-section combination 2, 0 if otherwise

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X_j = 1 if the criterion score is from treatment-section combination j, 0 if otherwise

P_1 = 1 if the criterion score is from person 1, 0 if otherwise

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.

P_n = 1 if the criterion score is from person n, 0 if otherwise

Treatments

	1	2	3
1	1	2	3
2	4	5	6
3	7	8	9
.	.	.	.
.	j-5	j-4	j-3
k	j-2	j-1	j

j = The total number of treatment-section combinations

Figure C1. Numbers Assigned to Treatment-Section Combinations Experiments 1 and 2.

Treatment

	1	2
1	1	2
2	3	4
3	5	6
.	.	.
k	j-1	j

j = The total number of treatment-section combinations

Figure C2. Numbers Assigned to Treatment-Section Combinations for Experiments 3 and 4.

C-3 FULL MODEL

The full model used in the analysis was:

$$Y = a_0U + a_1X_1 + a_2X_2 + \ldots + a_jX_j + b_1P_1 + \ldots + b_nP_n + e_1 \quad \text{(Model 1)}$$

C-4 QUESTIONS TO BE ANSWERED

The questions of the study were restated in a more explicit form to provide a guide for the statistical analysis. The questions and regression models developed to answer the questions are given in this section. The same basic questions were asked for all four experiments. The regression equations were of the same basic form for the four experiments but varied in the number of prediction vectors due to the different numbers of sections and treatments used in the experiments.

Question 1: Is there an interaction between treatments and sections for the relevant items of the criterion test (i.e., is the effect of each treatment the same for all sections)?

Question 2: Is there an interaction between treatments and sections for the incidental items of the criterion test (i.e., is the effect of each treatment the same for all sections)?

If interaction is present, the influence of the treatments will not be the same for different sections. If there is no interaction the treatments will have the same relative effect for all sections. The no interaction hypothesis can be stated:

$$\bar{X}_1 - \bar{X}_4 = \bar{X}_2 - \bar{X}_5 = \bar{X}_3 - \bar{X}_6$$

$$\bar{X}_4 - \bar{X}_7 = \bar{X}_5 - \bar{X}_8 = \bar{X}_6 - \bar{X}_9$$

$$\bar{X}_{j-5} - \bar{X}_{j-2} = \bar{X}_{j-4} - \bar{X}_{j-1} = \bar{X}_{j-3} - \bar{X}_j$$

Since the value of each mean as estimated from the regression model is a function of the associated weights for each variable, the hypothesis can be rewritten:

$$a_1 - a_4 = a_2 - a_5 = a_3 - a_5$$

$$a_4 - a_7 = a_5 - a_8 = a_6 - a_9$$

$$a_{j-5} - a_{j-2} = a_{j-4} - a_{j-1} = a_{j-3} - a_j$$

This implies that:

$$a_1 - a_4 = c_1 \qquad a_2 - a_5 = c_2$$

$$a_4 - a_7 = c_1 \qquad a_5 - a_8 = c_2$$

$$a_{j-5} - a_{j-2} = c_1 \qquad a_{j-4} - a_{j-1} = c_2$$

and

$$a_1 = c_1 + a_4 \qquad a_2 = c_2 + a_5$$

$$a_4 = c_1 + a_7 \qquad a_5 = c_2 + a_8$$

$$a_{j-5} = c_1 + a_{j-2} \qquad a_{j-4} = c_2 + a_{j-1}$$

The full model can be restricted to reflect the null hypothesis by substituting the above values for a_1, a_4, $\ldots a_{j-4}$ into the model. This yields the restricted model:

$$Y = a_0 U + (c_1 + a_4)X_1 + (c_2 + a_5)X_2 + a_3 X_3 + (c_1 + a_7)X_4 + (c_2 + a_8)X_5$$

$$+ \ldots + (c_1 + a_{j-2})X_{j-5} + (c_2 + a_{j-1})X_{j-4} + a_6 X_6 + \ldots + b_1 P_1 + \ldots$$

$$+ b_n P_n + e_2$$

Which simplifies to:

$$Y = a_0U + c_1T_1 + c_2T_3 + a_3S_1 + a_5S_5 + \ldots a_kP_k + \ldots + d_nP_n + e_2$$

Where:

T_1 = 1 if Treatment 1, 0 otherwise

T_3 = 1 if Treatment 3, 0 otherwise

S_1 = 1 if Section 1, 0 otherwise

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S_k = 1 if section k, 0 otherwise

However, examination of the section and subject vectors reveals that the section vectors do not add any new information since knowledge of the subject includes knowledge of his section. Therefore, the section vectors are redundant and can be eliminated from the model. The model may be rewritten as:

$$Y = a_oU+c_1T_1+c_2T_3+d_1P_1+\ldots+d_nP_n+e_2 \quad \text{(Model 2)}$$

Where:

T_1 = 1 if Treatment 1, 0 if otherwise

T_3 = 1 if Treatment 3, 0 if otherwise

The criterion scores were predicted using Models 1 and 2. The significance of the interaction was then tested by computing F from the RSOs for the two models.

Question 3: Are the mean scores of the subjects on the relevant items of the criterion tests significantly different when the subjects have used multiple choice adjunct or constructed response adjunct materials than when they have not used adjunct materials?

Question 4: Are the mean scores of subjects on incidental items of the criterion tests significantly different when the subjects have used multiple choice or constructed response adjunct materials than when they have not used adjunct materials?

Restated, the questions are: are the mean scores under treatments 1, 2, and 3 significantly different for relevant items? For incidental items? The null hypothesis is:

$$\bar{X}_{T_1} = \bar{X}_{T_2} = \bar{X}_{T_3}$$

or in multiple regression terms

$$a_1 = a_2 = a_3$$

$$a_4 = a_5 = a_6$$

$$a_{j-2} = a_{j-1} = a_j$$

or

$$a_1 - a_2 = 0$$

$$a_2 - a_3 = 0$$

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$$a_{j-1} - a_j = 0$$

or

$$a_1 = a_2 + c_1$$

$$a_2 = a_3 + c_1$$

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$$a_{j-1} = a_j + c_1$$

Where: $c_1 = 0$

Substituting into the full model yielded the restricted model:

$$Y = a_0U + a_2S_1 + a_5S_2 + \ldots a_{j-1}S_k + \ldots + d_1P_1 \ldots + d_nP_n + e_3$$

Since the section variables are redundant, they may be omitted from the model. The model may be rewritten as:

$$Y = a_0U + a_1P_1 + \ldots + a_nP_n + e_3$$

(Model 3)

The criterion score was predicted using Models 2 and 3. The significance of the difference of the mean scores was then tested by computing F from resulting RSQs. A significant F value obtained from this analysis indicates that at least two of the treatment means are significantly different.

Since there were more than two treatments used in Experiments 1 and 2, it was not possible to determine which pair or pairs of treatment means were significantly different when a significant F value was obtained. The Scheffé technique for multiple comparisons (Ferguson, 1966) was used to test the significance of the difference between pairs of means. This was accomplished by computing F for each pair of means and comparing the F value obtained with the adjusted F value (F') required for significance by the Scheffé technique. Regression procedures were used to compute the F values for each pair of means. This was accomplished by applying the following restrictions to Model 2:

Null hypotheses: $\bar{X}_{T_1} - \bar{X}_{T_2} = \bar{0}$ $\quad C_1 - C_2 = 0 = f_1$

$\bar{X}_{T_2} - \bar{X}_{T_3} = 0$ or $C_2 - C_3 = 0 = f_2$

$\bar{X}_{T_1} - \bar{X}_{T_3} = 0$ or $C_1 - C_3 = f_3$

Substituting the restrictions into Model 2 yields the following models:

$$a_0U + f_1(T_1T_2) + c_3T_3 + d_1P_1 + \ldots d_nP_n + e_4 \quad \text{(Model 4)}$$

$$a_0U + c_1T_1 + f_2(T_2+T_3) + d_1P_1 + \ldots + d_nP_n + e_5 \quad \text{(Model 5)}$$

$$a_0U + f_3(T_1+T_3) + c_2T_2 + d_1P_1 + \ldots + d_nP_n + e_5 \quad \text{(Model 6)}$$

Each model was used to predict the criterion score. The resulting RSQs were then used to compute F for each pair of means.

The above analysis also provided a basis for answering two questions related to the second area of consideration in the study - the relative effect of multiple choice and constructed response questions. The questions were:

Question 5: Are the mean scores of subjects on the relevant items of the criterion test significantly different when the subjects have used multiple choice adjunct materials than when they have used constructed response adjunct materials?

Question 6: Are the mean scores of subjects on the incidental items of the criterion test significantly different when the subjects have used multiple choice adjunct materials than when they have used constructed response adjunct questions?

C-5 ADDITIONAL ANALYSIS

A further analysis was made to provide additional information for evaluating the effects of adjunct materials. In this analysis, the proportion of variance accounted for by two additional variables, section

and instructor, was computed. Information on these variables was indirectly included in the regression analysis as part of the subject variable. However, it was not possible to determine the influence of the section and instructor variables from this analysis.

The proportion of variance accounted for by each variable was computed by developing two additional regression models. They were:

$$Y = a_0U + b_1I_1 + \ldots + b_kI_k + d_1P_1 + \ldots + d_nP_n + e_5 \quad \text{(Model 7)}$$

and $$Y = a_0U + c_1S_1 + \ldots + c_jS_j + \ldots + d_1P_1 + \ldots d_n + P_n + e_6 \quad \text{(Model 8)}$$

Where:

I_1 = 1 if the criterion score is from instructor 1, 0 if otherwise

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I_k = 1 if the criterion score is from instructor k, 0 if otherwise

S_1 = 1 if the criterion score is from section 1, 0 if otherwise

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S_j = 1 if the criterion score is from section j, 0 if otherwise.

In addition, the proportion of variance accounted for by the other variables in the study were summarized. They were:

Treatment (RSQ Model 2 minus RSQ Model 3)

Treatment-Section Interaction (RSQ Model 1 minus RSQ Model 2)

Subject (RSQ for Model 3)

It should be noted that the proportion of variance accounted for by the subject variable can be divided into three parts - Variance due to instructors, variance due to sections, and variance due to unidentified subject factors (such as aptitude, motivation, etc.). It should also be noted that knowledge of section implies knowledge of instructor. Therefore, the variance accounted for by instructor is included in the variance accounted for by section. Similarly since knowledge of subject implies knowledge of instructor and section, the variance accounted for by instructor and section is included in the total subject variance.

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